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The Use of Video Games for Training Users of Myoelectric Orthotics

Christopher Robert Knapp
Worcester Polytechnic Institute

Kyle Danley Baker
Worcester Polytechnic Institute

Patrick Edward Lynch
Worcester Polytechnic Institute

Sean Joseph Halloran
Worcester Polytechnic Institute

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by

Christopher Knapp _____

Kyle Baker _____

Patrick Lynch _____

Sean Halloran _____

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Professor Robert W. Lindeman, Advisor

Abstract

Assistive orthotics technology has rapidly increased in functionality in the past decade. In this field of medicine once mostly composed of static braces, the latest orthotic devices are now powered, allowing for people with disabled extremities to accomplish functional tasks. Myoelectric sensors allow users to command powered orthotics at will. However, the control of such devices remains nontrivial. In our studies we sought to use the motivational and educational power of video games to better train users of powered orthotic devices.

The results of our research led to several designs for games to do this, as well as an implementation of one such design, found to be effective in a small user study of powered myoelectric orthotics users. The results of this work show that an effectively engaging game controlled with powered orthotics can motivate users to use their orthotics more often, and that playing such a game is likely to improve one's competency in controlling their powered orthotics.

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1. Introduction

To accomplish our goal of training users of myoelectric orthotics, we did not only want to design games, we wanted to make games that we could measure the effectiveness of. To do this within the capabilities of our student team, we picked a particular orthotic device to work with and designed our game for that.

We focused our efforts on the MyoPro [7], a powered orthotic device controlled using signals sent to a user's biceps and triceps. Myomo is the company that produces the MyoPro. The MyoPro was designed in order to help people who have lost use of their arm, due to a stroke or an accident or for other reasons, move their arm again. When the user has the MyoPro on, there is a sensor on the user's biceps and a sensor on the user's triceps on the arm that the MyoPro is going to move.

1.1. Modes of Operation

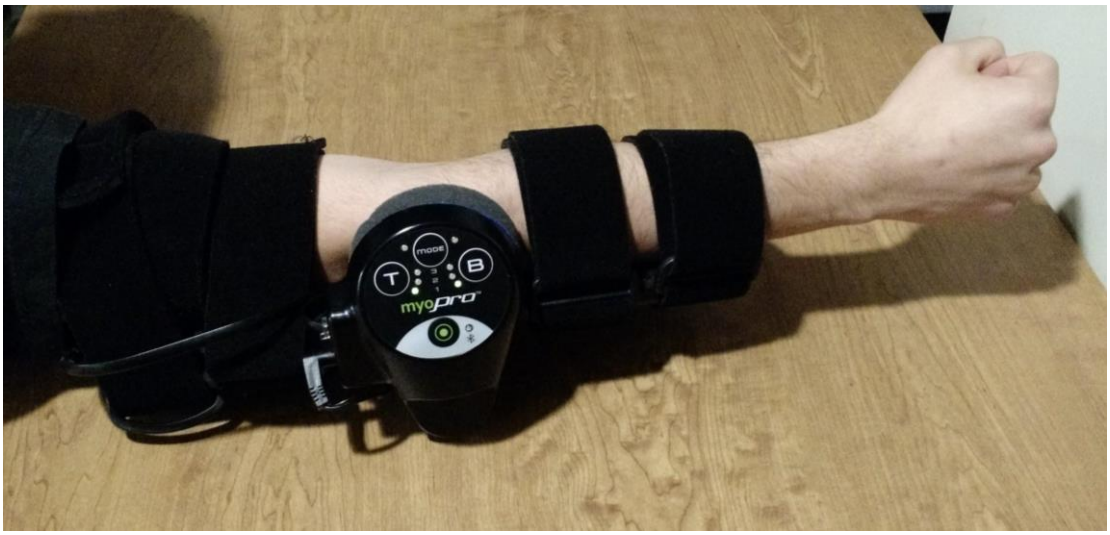

Figure 1: The MyoPro extended

The MyoPro has three modes: biceps, triceps, and dual. In biceps mode, the MyoPro rests with the user's arm extended, as seen in figure 1 above. When a user wants to flex his or her arm, he or she concentrates on flexing his or her arm. This sends signals to the user's biceps telling the muscle group to flex the arm. The sensor on the user's biceps then reads these signals and tells the MyoPro to flex, thus moving the user's arm. To extend the user's arm, the user stops flexing their biceps, through attempting to relax their arm, and the MyoPro will then relax causing the user's arm to extend.

Figure 2: The MyoPro flexed

Conversely, when in triceps mode, the MyoPro rests with the user's arm flexed as seen in Figure 2 above. If a user wants to extend his or her arm, the user thinks about moving his or her arm down. The user's brain will send signals to his or her triceps. These signals tell the triceps to lower the user's arm. The sensor on the MyoPro will pick up these signals and lower

the user's arm. When the user wants to flex his or her arm, the user has to stop thinking about extending his or her arm and the MyoPro will flex.

Alternatively, in dual mode, there is not a designated resting position. In both biceps mode and triceps mode, there is a threshold for the signal. When the user sends a signal that surpasses the threshold for the appropriate muscle, the MyoPro will react. In dual mode, the MyoPro will read the signals from both the biceps and triceps. Whichever threshold is passed first determines the direction that the arm will move in. If the biceps threshold is passed, then the MyoPro will flex, and if the triceps threshold is passed, then the MyoPro will extend.

1.2. Controlling Arm Movement

Learning to use impulses once used to control one's limb to instead control a human made device like the MyoPro can be difficult to do. One of the goals of our project is to make a game incorporating the MyoPro as an input device so that users will be motivated to practice using the MyoPro. Since the users have lost use of their arm, it is difficult for them to move a mouse or move their hand around a keyboard which makes it very difficult, if not impossible, to play most computer games.

In order to achieve these goals, we began by researching the topics of orthotics and prosthetics, games for health or training, and motivation. We then came up with possible game designs incorporating the MyoPro and evaluated the pros and cons of each design. We decided on making Backgammon and implemented it. Once we had the game in a working state, we conducted user testing.

2. Background

2.1. Orthotics and Prosthetics

Orthotics is the branch of medicine for using devices and apparatus for supporting or assisting some part of the human body. Simple examples of orthotics are splints and braces, structures that are usually rigid and hold some limb in place. More advanced orthotics are powered and allow users to accomplish functional tasks like carrying bags and holding things down on a table, important tasks often overlooked by people with healthy extremities.

The orthotic device we worked with for this project was the MyoPro made by Myomo. The MyoPro is a powered orthotic elbow brace that helps individuals with long-term upper limb weakness. With myoelectric sensors on the biceps and triceps muscles, the MyoPro can sense the attempted muscle movements of people with very little muscle tone. With this, users can flex or extend their arm at their elbow by attempting to move their biceps, triceps, or a combination of the muscles in a dual mode.

2.2. Games for Health/Training

The video game industry has grown to rival other long-standing media industries, more than doubling Hollywood's box office income in 2010 [6], something that is no small feat, causing it to be considered as a serious medium more and more. Companies have begun exploring the practical potential of video games. Some commercially successful examples of this include the Sony EyeToy Kinetic and Nintendo's Wii Fit and Wii Sports, all geared towards keeping the player physically active [8].

The act of play has several attributes that make it a strong candidate as a medium for a health or training based product. For one, the act of play is voluntary, and as such it is intrinsically motivating within itself such that the user is motivated to play from their own will [1]. Playing often has some sort of active engagement, often a combination of physical and mental engagement. And lastly, playing is distinct from other behavior by having a make believe quality to it, separated from reality. Thusly, playing is an effective form of stress management and catharsis [1]. The implications of this being that games can be a strong motivator for a patient if incorporated into their treatment, which is the focus of this project.

2.3. Distraction Therapy/Immersion

Immersion is the concept of becoming deeply involved with a book, game, or other task on a mental level. Immersive games give the player a chance to escape their own lives or help distract from other aspects, and using such for therapy has served as an effective method for improvement [3].

Similar to how learning in games allows for a deeper level of engagement and thus a deeper level of learning, therapy becomes less stressful when focus is no longer on the task as an act of rehabilitation [3] [9]. By turning the task into a part of a game it becomes less of a job or chore, and more like something the engaged party is doing for a purpose of fun [9]. A focus on fun over the task at hand serves to distract from the stress and pains that would normally be focused on since the brain is otherwise occupied with the game [3]. The same principle applies to the use of games for teaching how to operate the Myomo orthotic arm. By focusing on the

game while they learn to control the device, we believe it will make the control become second nature over time based on the concept of muscle memory.

In a study on burn patients, it was found that using Virtual Reality (VR) to distract from the pain, distraction therapy, when bandages had to be redressed significantly reduced the pain that the participants felt, averaging around a 33% reduction in pain [3]. By using up the entire span of the patients vision, they were prevented from seeing their own wounds being redressed, helping to keep the process out of mind. Other methods of distraction were also chosen by some participants in the study, but only television and the VR showed any significant reductions in the patients' pain [3]. The use of the deeper levels of immersion with a VR headset, in this case the Oculus Rift, was an idea that was considered for use in our game designs to fully immerse the players.

2.4. Motivation

Our project was, in part, motivated to help increase the healthiness of the users of our game, as well as train them in using their MyoPro, and to use the MyoPro more often. We read research in order to guide our actions in the most appropriate direction. There has been work done to add physical activity to video games in games such as *Dance Dance Revolution* and *Wii Sports* [4]. These games show that people who are typically sedentary may be motivated by games in order to be more active.

While planning the project, we considered issues such as compliance to exercise programs, self-efficacy, self-image, and peer support. Traditional games solve some of these problems. For example, multiplayer games exist where peers can work together as a team.

However, if a naive approach is taken, it can be detrimental to a patient's motivation [4]. One way that may be tempting to indicate a patient's progress is by increasing the size of the muscles on a patient's avatar. This has an inherent issue though; if a first patient sees a second patient's avatar and the second patient's avatar is much more buff than the first patient's avatar, then the first patient may be demotivated, particularly if the second patient has not put in as much effort as the first patient.

Another issue that may arise is the fact that some patients are more naturally skilled than other patients; this is not because some patients are worse than others but because some patients are more physically able than others. Games for health must not allow more physically able patients to be more skilled at the game than the less physically able patients. If the game permits this, then less physically able patients will not only be less motivated to play the game, they will be demotivated because they are entirely incapable of doing as well as the more physically capable patients [4].

Music is an important factor in motivating patients [4]. Experiments have shown that music can decrease a patient's physical exertion while exercising as compared to when a patient is either listening to a metronome or no music at all. Upbeat music, as compared to slower music, leads to greatly reduced feelings of anger, fatigue, and depression. A couple of reasons that music causes these results are because the music may provide a distraction from physical discomfort or the user may have positive memories tied to the music being played.

Giving a patient guidance is important in motivating the patient because starting an exercise program can be intimidating [4]. If there is an instructor with a strong knowledge of

physical activity leading the exercise game, then patients will be more motivated to stick with the game. Other important factors are that the instructor must be skilled at teaching, enthusiastic, and able to give personal attention to the patient.

It is possible for the instructor to be another player, an artificial intelligence (AI), or even quests [4]. Guiding new players can be a chore for more experienced players. It may be recommended that experienced players be incentivized for helping the new players by giving the more experienced players more or better rewards. Alternatively, the fact that this is a computer program means that an AI may be programmed in order to give players guidance. It is not even necessary that this guidance be a character in a game; it could be quests or even directions on a map.

Self-efficacy is how much control a person believes they have over the outcome of a situation [4]. Self-efficacy is a major factor in how motivated a user may be to improve themselves. In order to improve a user's self-efficacy, it is important to have long-term and short-term goals. The long-term goals give the user something to look forward to. The short-term goals give the user something that they can achieve quickly. The short-term goals can lead to the long-term goals. For example, in some games, users are given a currency for completing a game. The currency can then be saved up for a prize that is bought with this currency. In this example, the short-term goal is to obtain currency and the long-term goal is to obtain a prize.

3. Proposed Designs

The team proposed multiple game designs as possible games for the final project. Among these designs were Backgammon, a *Galaga*-type game, *Wario Ware*-type mini-games, a first-person Tower Defense game, Casino games, and an *Angry Birds*-type game. The game that was decided on was Backgammon, but there are important ideas to be taken from the other proposed designs.

3.1. Angry Birds

In the Angry Birds-type game, the idea was that the player would use the arm to control a slingshot. At first, the player would use the arm in order to choose an angle at which to launch an object. This would be done by flexing the arm in order to increase the angle between the ground and angle of launch, and lowering the arm in order to decrease this angle. It is common for users to put their elbows on tables in order to allow their arms to rest. This makes it easy to set the launch angle parallel to the ground when the user is resting his or her arm on the table. The MyoPro is able to flex further than 90°. It is important that the angle of launch is not equal to the angle at which a player's arm is flexed. After the angle of launch is determined, the player would then need to set the amount of power to be used in the launch. This can be done simply by setting the power of the launch to 0% strength when the player's arm is resting on the table and 100% when the MyoPro is fully flexed. One reason that this game was not chosen for the game to be made is that aiming the slingshot required precision. It is difficult for a patient to hold his or her arm at a precise angle for long enough to decide if that is the angle at which he or she wants to launch an object. Myomo has created a mode of operation that

allows users to hold their arm in place better called dual mode. Dual mode takes input from the patient's biceps and triceps in order to determine if the MyoPro should move or not.

A definitive art style was never discussed in detail, though there were suggestions of possibly making the game on a simple base that would then have skins that could be swapped out, allowing for a small selection of style. This would have allowed for the game to appeal to multiple groups more easily by having more targeted styles for demographic selections. The problem would have then been making sure the skins were either easily changed for the player, or were set up beforehand based on who would be playing.

3.2. Galaga

Another game design that was proposed was a *Galaga*-type game. A prototype of this game has been created where the player is actually playing *Galaga* but controlling the game using the MyoPro. This game was very popular in small user test environments where the users were patients who used the MyoPro. In the game, the user would control the horizontal position of the ship by flexing and extending his or her arm. The ship would automatically fire at a regular interval. Slowly, enemies would come on screen. As the player defeated these enemies, more enemies, in an increasing difficulty, would come onto the screen. Due to copyrights, we could not use *Galaga* itself, so we designed a *Galaga*-type game. The style was going to be made to look similar to the original, so that the aliens you shoot at would be an homage to the original, likely in similar design, but with greater detail and style, as it would not be limited to the same pixel resolution of the original game. The box and arcade case designs of the original set ups depicted the aliens as being insect like in appearance, so the ships would

have been bug based, instead of being traditional space ships or alien creatures. This is shown in Figure 3. The color scheme was undecided, but the colors we were considering were going to be in a scheme similar to the original, toned down and muted to better fit the new designs.

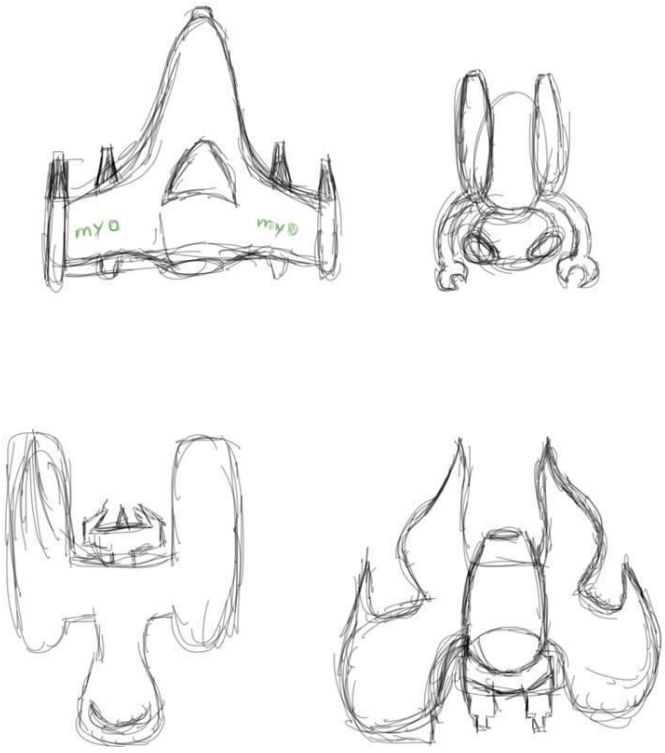

Figure 3: Early Galaga-type concept art

3.3. Tower Defense

We also considered a first person tower defense style game, wherein the mechanics were similar to the *Angry Birds* style idea, having the player extend their arm fully to launch an object. However, rather than launching objects at stationary structures and targets, there would be waves of enemies approaching the tower on which the player is situated. In biceps mode, flexing the MyoPro would lift an object to throw, and pressing spacebar would throw it, where in triceps mode launching is done via extending the user's arm, and in dual-mode both

actions are controlled using the user's arm. One idea proposed for this game was having multiple lanes or directions the enemies could be approaching from, forcing the user to keep checking the different sides of their tower throughout the game. Coupled with this idea was the prospect of adding Oculus Rift support, where the player would check the different sides by turning their head. Ultimately, this game held lots of promise, and while we believe it would have seen great success, it was beyond the scope of the time we were allotted to complete.

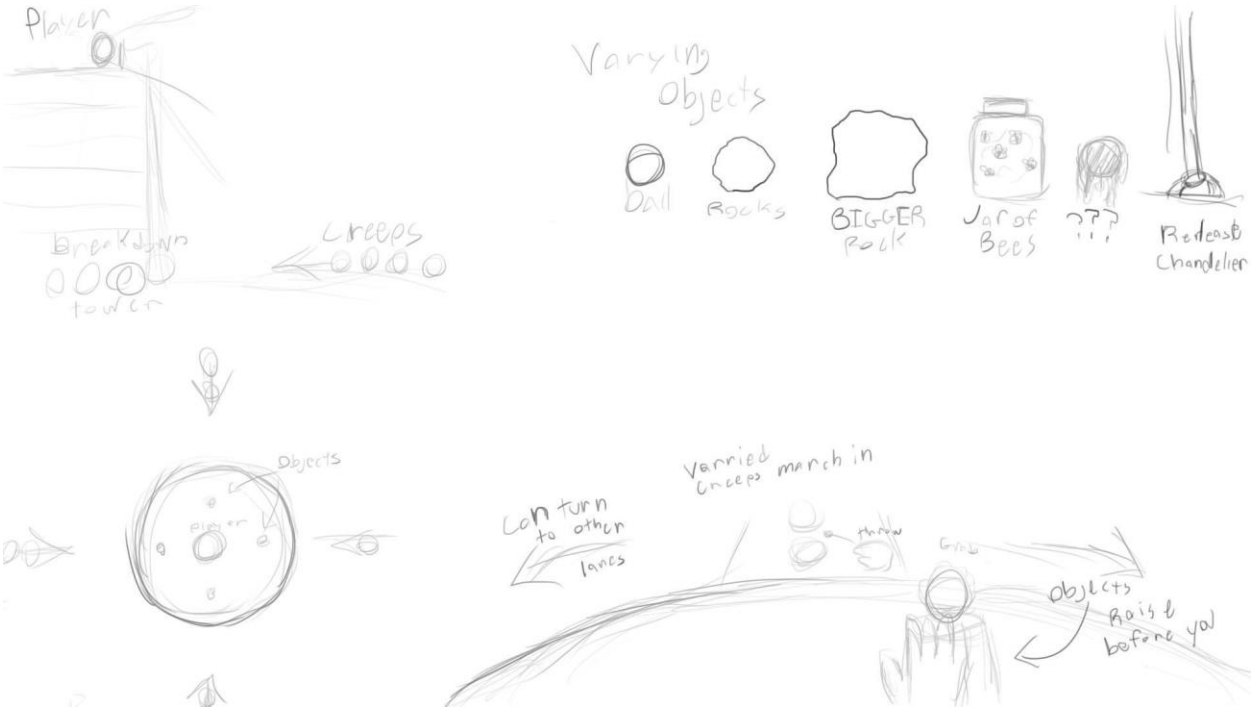

Figure 4: Tower Defense Game Concept Art

Typically tower defense games have a sort of miniaturized set of towers that range from super stylized to semi-realistic. Since our planned game was to be a single tower on which the player stood and threw objects at approaching enemies, like in Figure 4, it was planned to have a more realistic style for the tower since it would be right in front of the player. The enemies would have been something more along the lines of cartoon monsters of some kind.

Alternatively they would have been attacking knights or a similar trope. To stop the invaders, the player would be throwing objects at them. In the game there would be a realistic arm to represent the player's arm without the MyoPro on it, so that the focus is on the game. The objects to be thrown would range greatly but would generally be simple rocks or bottles with varying objects suspended inside them. The landscape beyond would be either other towers along a lane, as if you were actually part of a tower defense game as one of the towers, or rolling hills to allow the enemies a space to spawn from out of sight. The rolling hills would likely have been without an actual grass texture, instead bearing a flat, muted color to go along with the enemies.

3.4. Minigames

One of our more fleshed out ideas that wasn't dropped until much later was a collection of minigames, similar to of *Wario Ware*. There would be a medley of various minigames, ranging from simple everyday tasks such as turning on a light switch within the allotted time, to whack-a-mole, and even a *Galaga* style minigame. We chose this due to the innate structure of the minigames design lending itself to short term motivation. Minigames each have very clear and easily attainable goals, with no large time commitment required. To achieve long-term motivation, each minigame would award some in game currency upon completion, allowing the player to see their progress as they continue completing minigames. It was never decided exactly what the currency would be spent on, but ideas were on extra minigames, or possibly bonuses to aid the player in future minigames such as allowing the player extra time to complete each minigame. This arrangement created both short-term goals and long term goals

for the player, where the short term goals feed into the long term goals, an ideal situation for fostering continued motivation to keep playing.

Figure 5: Minigame concept art

The overall feel of the game would be cartoony and upbeat, with some unified style between everything as seen in the example games within Figure 5. We planned on having all the games connected via a common zone where the player is when not playing a game, through which they would reach the individual minigame or playlist. For that common zone, we thought of several ideas, eventually deciding on a park, and also decided that having the minigames themselves take place in the same park would create a more unified experience. As the player successfully completed a number of minigames, the difficulty would slowly rise, easily adjustable through the time allotted in which to complete the minigame. This increase in difficulty could also be conveyed through the music picking up in tempo or modulating slightly

higher, as well as the background visuals speeding up. Unfortunately, just as was the case with the tower game, there was not enough time for us to allocate towards this idea, and as such it was beyond the scope of what we could attempt.

Figure 6: Example of Wario Ware art style [5]

The game designs each lent themselves to one style over another. Our minigame idea was heavily influenced by the Wario Ware games developed by Nintendo, so the style would have been similar with bright colors and heavy outlines as seen in Figure 6. The style is fairly simplistic in its shading with lots of smooth lines and surfaces, which appeals to many though typically appeals to a younger audience. Models to be used for the games were to use a shader to emulate the heavy outlines, with textures that would have simple baked on shadows or pre rendered shadows to keep lighting problems down and maintain the styles feel. To try and avoid targeting the game at too young of an audience, there would be a bit more realism within the game so that the style wouldn't be completely alienating to those that would find the colors

excessively bright or see the style as childish and unappealing. Among the original ideas this one was the most stylized.

4. Final Design

The game we finally decided upon was Backgammon. As this is a well established board game, there wasn't much that needed to go into designing the logic of the game itself, however the challenge came in making it an engaging experience through use of the MyoPro. This was chosen as a proposed idea due to its relative ease to complete compared to the alternatives, while also having a high likelihood of positive reception among the target audience of MyoPro users. Having a wide demographic, not being overly demanding technically, and the fact that it is already an established game meant that we did not have to invent an entire game from scratch. Backgammon allows the player to play at their own pace, meaning it would not overexert a player who could not keep up with a faster game, nor bore a player who could play very quickly.

4.1. Controls

Our original design had the player begin their turn by rolling the dice by pressing spacebar with their free hand. To pick a piece to move, they would first cycle through the four quadrants of the board by flexing or extending their arm, then select one using spacebar. Selecting a piece within the selected quadrant would follow a similar fashion, cycling through points from which a valid move can be made by using their arm and selecting one with spacebar. The selection would continue cycling at a fixed pace for as long as the player kept their arm flexed or extended. This decision was made in an effort to drastically reduce the number of times the player's arm must extend or flex, so that they do not tire as quickly, allowing them to play the game for longer. Eventually this process was fine tuned so that the

step of picking a quadrant first was skipped entirely, as the number of valid points to move from never exceeds more than a few points. This control scheme also allows for all MyoPro control modes to be used, as the selection cycles as long as the arm is flexed or extended, it does not matter which. During game play, selections are highlighted to show that they are either selected, or selectable, for the player. The piece that is currently selected will have a green highlight as in Figure 7, to indicate that confirming selection with the space bar will use that piece for movement. Selectable pieces are highlighted in yellow, as seen in Figure 8. As the user flexes their arm to change their selection, the next selection highlights to green, while the previously selected piece reverts back to yellow.

Figure 7: Example of current selection highlighting

Figure 8: Example of possible selection highlighting

4.2. Stylistic Choices

One of the primary goals of our Backgammon design was to create a relaxing experience for the player. In part, this is reflected through our control scheme which minimizes the motion required from the player's arm. We also sought to achieve this through the stylistic aspects of the game, such as the musical direction of the game. The two main ideas for music we had were either classical or smooth jazz, which ultimately we decided on the latter, due to its more

relaxed nature. The jazz track was written with a thin texture, in other words a small arrangement of instruments, to a medium paced tempo. The song has an ostinato in the drum kit and bass, which is a repeating line throughout the song, giving it the capability to be looped seamlessly ad infinitum. An effort was put into not having any jarring or sudden moments in the piece, to make it as subdued as possible, but still preserving a rich tone and harmony.

Backgammon is not something that would commonly be considered a new game outside of the sense of being introduced to it recently, and as such a less stylized art motif seemed better fitting. The target demographic was fairly spread, but stroke patients are some of the most common users and strokes are more common in an older demographic. By sticking with a realistic art style, the game is kept grounded in what is well known.

Figure 9: Our Backgammon board

Backgammon boards are typically muted colors, so that theme was kept in the props and background elements, as in Figure 9. While not explicitly necessary to have more than just the board, which could have filled the whole screen, having more things in the background

keeps it from looking too completely bland and makes for space to add in the instructional panels for what to do.

4.3. Implementation

With all of the designs we made, we were able to implement our version of Backgammon in the course of the project. Much of the architecture of this implementation would be the same for all the designs described in this paper. All of the designs were intended to be implemented in the Unity3D game engine.

4.3.1. Backgammon Hardware Connection

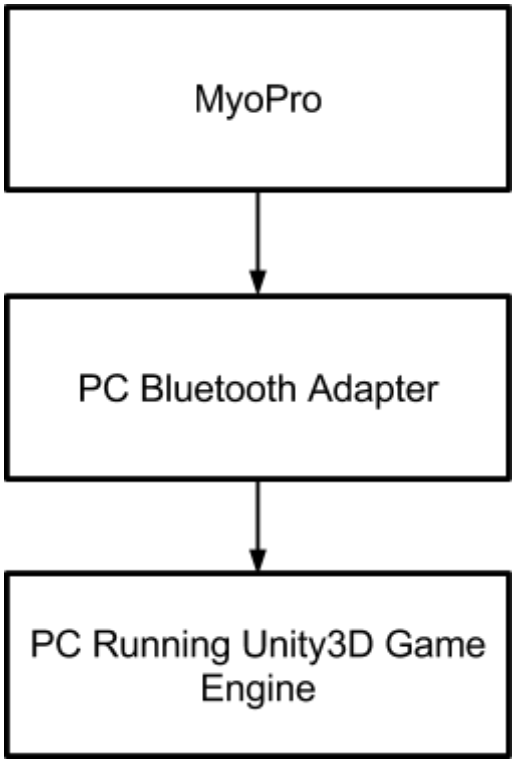

Figure 10: Stream of data from MyoPro to Unity

The stream of data across from the MyoPro device to the game is shown in Figure 10. The MyoPro sends data across a Bluetooth connection between itself and a Bluetooth adapter

in the PC running the game. All communication between the game and the MyoPro is handled across this Bluetooth connection.

4.3.2. Backgammon Software Architecture

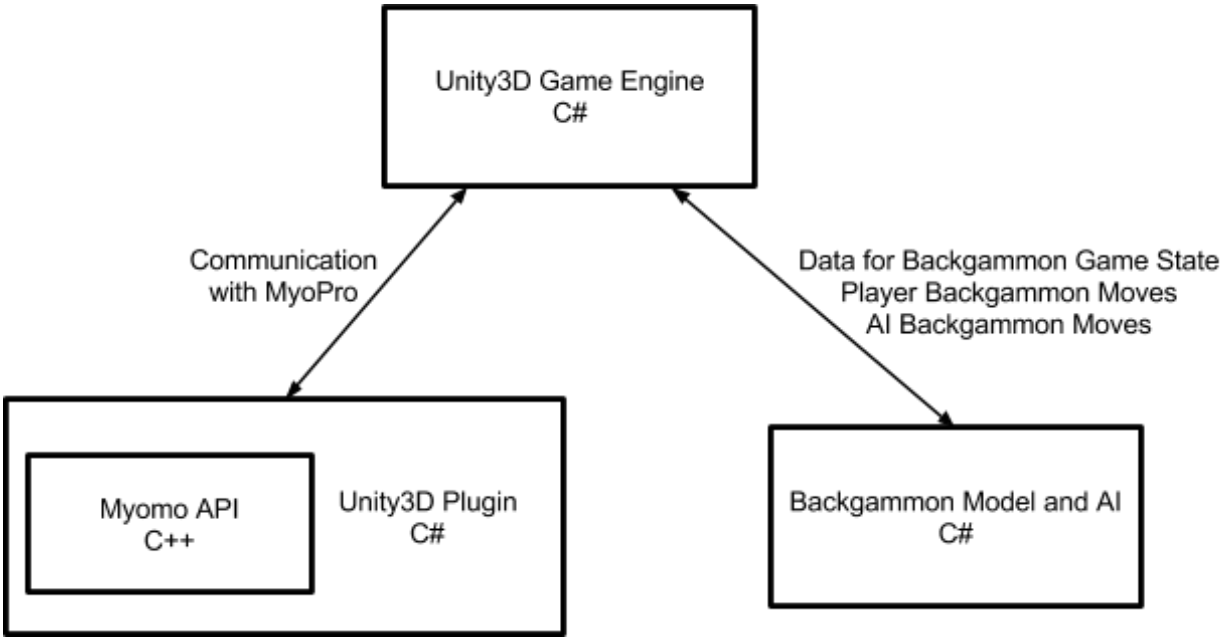

Figure 11: Components of Backgammon software design

Our implementation of Backgammon is divided into three main components as seen in Figure 11. This consists of the Myomo Unity Plugin that handles communication with MyoPro, the model of the Backgammon game and the AI the player plays against, and the game code in the Unity3D engine that allows the player to interact with the game.

The Myomo Unity Plugin wraps Myomo's native API for interfacing with the MyoPro in a C# library that Unity can use. It handles all device I/O and provides useful Unity prefabs for using the device as an input device for the Unity engine.

The Backgammon Model handles updating the state of the game as well as validating moves with the rules of Backgammon. It exists in a package outside the game for independent unit testing and playing games via command line for further testing.

All of these components are tied together with scripting in the Unity engine. Here, the game reads the data from the Myomo Unity Plugin, and changes the selection of pieces on the Backgammon Model appropriately. All UI and user interactions are handled here. To highlight moves the user can make, a Unity script asks the Backgammon Model for all possible moves.

4.4. Backgammon AI

The Backgammon model's AI is not very intelligent, because creating a Backgammon AI was not the purpose nor within the scope of this project; however, the AI correct. This means that the AI will make valid moves within the rules of Backgammon that progress it towards winning. It simply chooses between these valid moves randomly.

5. Evaluation Methodology

To evaluate the implementation of our Backgammon training game, we conducted a session of user testing with three MyoPro users. The session consisted of an introduction to the rules of a normal game of Backgammon with a physical Backgammon set, a survey before the users tried the game, evaluation of the user's performance in the game as they played it, and a survey after their trial of the game.

5.1. Instructions Given to Users

To begin testing, our three users all entered a conference room where we set up a real physical Backgammon set. Two of us then played the opening of a game with this set, explaining each of our moves as we made them.

Figure 12: Backgammon board used to introduce testers to Backgammon

Using the board set up as in Figure 12, we showed users what initial moves they had to make based on the roll of the dice. After each player had moved, we rolled doubles, and explained this mechanic to the players. We explained hitting opponents pieces, and then moving off the bar. Lastly we set up the board as it might look at the end of a game, so that we could explain moving pieces off the board and the victory condition.

Although many of these rules are abstracted in our game through features like highlighting the pieces which can be moved, the version of the game we were showing did not explicitly explain the rules of Backgammon, and we wanted our users to have a base level knowledge of the rules of Backgammon, so that they could be evaluating our implementation of Backgammon, and not stuck on the fundamental rules of the board game itself.

5.2. Pre-Trial Survey

In this survey we wanted to evaluate each user's experience with games, both physical and electronic, and each user's experience with the MyoPro, as well as some basic demographics questions. We surveyed the average amount of game playing that each user did, and on what platforms. We also asked for each patient's familiarity with Backgammon before that date. The survey asked how often the users put on their MyoPro and for how long. Specifics of how they liked to use their device were also asked, particularly if they prefer biceps, triceps, or dual mode.

5.3. User Testing

After completing the pre-trial survey, we simultaneously tested each of the three users with one student assisting them in setup and answering their questions along the way. Myomo engineers were also present to assist with any possible MyoPro related issues during testing.

Each student attended to a user during testing, and also set up recording software on the computer running the game. This allowed gameplay to be recorded while also capturing footage from the webcam, which was pointed towards the user, so both the user and their respective gameplay could be watched in parallel and observed. Users were asked for their consent to be recorded before this setup was done. Each student took notes on the user's actions while they were playing. Users were allowed to play for as long as they liked, until they were either tired or no longer interested.

5.4. Post-Trial Survey

The users were given another survey after they played the game. In the post-trial survey, each user was first assessed as to how tired they felt, and were further questioned about any possible frustration with the controls or other aspects of the design. The user was finally asked some clarifying questions to find out if there were any instructions not well conveyed to the player.

6. Results

Pre Testing Survey Questions (in order):

1. Age
2. Gender
3. How frequently do you play electronic video games?
4. How often do you play board games?
5. How do you play games most?
6. Have you ever played Backgammon?
7. How often do you use your MyoPro?
8. How long do you use the MyoPro for at a time?
9. How experienced are you with using the MyoPro?

   (Inexperienced-Experienced, 1-5)
10. What control modes do you use on the MyoPro?
11. What control mode do you use the MOST on the MyoPro?

Table 1: Pre Testing Survey Results

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
61	Male	< 1 hour a week	< 1 hour a week	I don't really play games	I have before and think I remember the rules	Once a day	15 minutes	4	Biceps Mode	Biceps Mode
39	Male	1-3 hours a week	not at all	PC or Mac/ Smartphone	Never	Once every other day	15 minutes	4	All	Biceps Mode
51	Female	4-6 hours a week	< 1 hour a week	PC or Mac	Never	Once every other week	30 minutes	4	Biceps Mode	Biceps Mode

Post Testing Survey Questions (in order):

1. How tired are you after playing this? (not tired - exhausted, 1-5)
2. What did you think of the controls of the game?

   (very confusing - understandable, 1-5)
3. Did the popup instructions help you understand what to do better?

   (did not help - helpful, 1-5)
4. Was there anything difficult to see or read in the game?
5. Is there anything you are still unclear about?
6. How long do you imagine you would play this at a time?
7. How often do you imagine you would play Backgammon like this?

8. How likely would you be to put on the MyoPro just to play Backgammon? (not likely - very likely, 1-5)
9. How likely would you be to play Backgammon if you already had the MyoPro on? (not likely - very likely, 1-5)
10. How would you rate the artistic style? (hated it - loved it, 1-5)

Table 2: Post Testing Survey Results

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
2	4	2	Nothing	Nothing	Half an hour	Once a week	5	5	4
5	2	1	Hard to see what the dice roll was, AI moves	Nothing	Half an hour	Once a month	1	3	4
2	4	3	Computer's turn	Nothing	Half an hour	Once a week	5	3	5

The results from our surveys and observations were overwhelmingly positive, shown in Table 2. Everyone reported extreme ease of control and clarity on what to do. Only one of the player testers reported being even remotely tired, however that tester had just had Botox injected in the arm used to control his MyoPro the day before, naturally making his arm more fatigued. All testers reported that they would play the game if they were using the MyoPro already, and all but one reported that they would put the MyoPro on just to play the game. One surprising response we got, though, was that the pop up instructions were unneeded, most testers not even noticing them.

7. Future Work

Though a large amount of effort was put into this project, no project will ever be entirely complete. There will always be room for improvement and, for this project, we have compiled a list of features that either can be improved upon or added to the game in order to make the users' experiences better. Among these are increasing the quality of the artificial intelligence, multiplayer games, adding in animations for moving pieces and rolling dice, a better user interface and improving piece highlighting, adding sound effects, adding an in-game instruction screen, adding functionality to allow devices to reconnect, and including the ability to save a game.

7.1. Artificial Intelligence

In its current state, the artificial intelligence is non-ideal. It figures out every valid move and then chooses a valid move randomly. This can be improved in many ways. First, the way it figures out every valid move is inefficient. It attempts to do every possible move and we run the move through a move validation function, if it is valid, the move is added to a list. The artificial intelligence then randomly chooses from these moves. In the future, an artificial intelligence can more efficiently determine what moves are valid, and then assign a score to each valid move based on a heuristic. Once artificial intelligence has scored each of these moves, it can intelligently decide on one of these moves.

7.2. Multiplayer

It is possible to write this game in a way that allows for multiplayer interactions. It is possible to have both local and online interactions. The online interactions may operate on a

client server model or a peer to peer model. For local multiplayer, it would require a game programmer to displace the artificial intelligence and put another player in its place. It is possible to set up the second player such that this player either also uses a MyoPro or a keyboard. It would be important to have both options so that MyoPro users are capable of playing against each other as well as other people who do not use the MyoPro.

7.3. Animations

Currently, the game just uses a random number generator and displays the numbers that the user got instead of rolling dice. For future work, there can be a dice rolling animation and in the back end there can be a random number generator. It is possible to write code that will make the dice land on the numbers that were randomly generated. This will be more appealing to the user as it better emulates a real life game of Backgammon. Additionally, in order to better emulate a real Backgammon game, there should be an animation so that the user can see where the pieces are moving to and from, particularly when the artificial intelligence moves a piece because, in its current state, the move is instantaneous. It may also be beneficial to add a delay to the artificial intelligence's move before it even moves a piece in order to make a user believe that it is taking time to think. As mentioned previously, the values of the dice that are decided by the random number generator are just displayed as text numbers. In a future version, it would be better to display these values as the dice rolled and, as the user applies each die to his or her move, the used die either disappears, grays out, or indicates use in some manner.

7.4. Highlighting

The highlights applied to pieces are currently difficult to see, based on feedback from user testing. This makes it difficult to distinguish between a selectable piece and a non-selectable piece. It is also difficult to see a selectable point to move the piece to. Some possible solutions to this include adding a pattern to the highlighted pieces so that there is more to be seen than just a halo surrounding the piece. When a piece is being moved to a point, it may be advantageous to highlight the entire triangular point rather than just placing a halo to where a piece would be moved to.

7.5. Sound Effects

Sound effects can be beneficial to the user because then the user gets an auditory confirmation of what he or she just saw happen in the game. Some examples of useful sound effects include a win noise, a lose noise, a noise to indicate that a piece was hit, a noise to indicate that it is the user's turn, and a noise that happens when a player puts a piece into the home.

7.6. Instructions

During user testing, we were able to give users a jump start on how to play Backgammon as well as how to use the MyoPro to play our game of Backgammon. This would be unrealistic to do with every MyoPro user so it would be beneficial to add an in-game instruction page. This would allow a user to be able to figure out for himself or herself how to play the game if the controls are not intuitive enough as is.

7.7. Reconnecting and Saving the Game

During user testing it became apparent that there is a need to add functionality so that a disconnected device can reconnect and pick up in the middle of a game. Users would sometimes just get up and walk to the restroom which is far out of the range of the Bluetooth device that the MyoPro uses. Additionally, users were sometimes unable to complete a game in one sitting because it was too strenuous. Allowing users to disconnect their device and come back to the game later and reconnect their device would solve this problem except it would introduce another problem; the user would need to leave the game running for the full time that they were not playing. This clearly poses a problem because a user may want to restart his or her computer. In order to solve this problem, a save game feature must be implemented. This save game feature would allow the user to save the game's state, close the game, later reopen the game, and then restore the game's state.

8. Conclusion

Ultimately, we were not able to complete everything that we had planned, as laid out in future work. This was due simply to time constraints leaving us unable to accomplish everything within the time allotted. Of the ideas we originally proposed to Myomo, minigames as a whole was dropped and Backgammon was left in a playable, but not entirely complete state. We were, however, able to create a Backgammon game that is functional and is playable through the MyoPro device.

We believe we were successful in completing the goal we set out to achieve, being to create an experience that motivates a MyoPro user to use their MyoPro to play a game, and thusly motivates them to practice using their MyoPro and moving their arm. This is based on the results we received from our user testing, where everyone played a full game of Backgammon to completion and everyone was engaged with the game for the duration. Every player tester had positive feedback about the game, and all mentioned that they would play the game using their MyoPro if they were already wearing it, and all but one said that they would put their MyoPro on for the sole purpose of playing the game. One player tester even requested the beta demo used to be installed on their personal computer before leaving, showing the interest towards using the MyoPro device to play a video game, and specifically the Backgammon game we created.

Due to only having three users test our game and provide feedback, it would take additional testing to prove whether or not playing our game results in the skills for playing the game translating to skills using the MyoPro device. However, even so, we believe that this is the

case. The actions taken during a typical session using the MyoPro and those taken playing our game are identical, requiring only flexing or extending the player's arm. As such, we would equate the process of playing the game to that of typical MyoPro use. Ergo, we also assert that in motivating MyoPro users to play our game successfully, we are motivating them to practice using their MyoPro and exercise moving their arm, which is exactly the goal we sought to achieve.

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